

# Multiwavelength optical observations of chromospherically active binary system OU Gem

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## Abstract.

We have analysed several multiwavelength optical observations ( $H\alpha$ ,  $H\beta$ ,  $H\epsilon$ , Ca II H & K, Ca II IRT lines) of chromospherically active binary system OU Gem, taken in three observation runs: March 1996, April 1998 (using the SOFIN spectrograph and the Nordic Optical Telescope) and January 1999 (using the ESA-MUSICOS spectrograph and the Isaac Newton Telescope). The spectra show double  $H\alpha$  and  $H\beta$  absorption lines, but after applying the spectral subtraction technique, clear excess emission is seen in both components. The two stars have the Ca II IRT lines in emission, strong emission in the Ca II H & K lines and small emission in the  $H\epsilon$  line. Although they have very similar spectral types, the cool one is more active than the hot one in all runs, except for MUSICOS run, and in all spectral lines, except for Ca II IRT lines.

## 1. Introduction

OU Gem (HD 45088) is a bright ( $V=6.79$ , Strassmeier et al. 1990) and nearby ( $d=14.7$  pc, ESA 1997) BY Dra-type SB2 system (K3V/ K5V) with a 6.99-day orbital period and a noticeable eccentricity (Griffin & Emerson 1975). Both components show Ca II H & K emission, though the primary emission is slightly stronger than the secondary emission. The  $H\alpha$  line is in absorption for the primary and filled-in for the secondary (Bopp 1980, Bopp et al. 1981a, b, Strassmeier et al. 1990). Dempsey et al. (1993) observed that the Ca II IRT lines were filled-in. It is interesting that the orbital and rotational periods differ in 5% due to the appreciable orbital eccentricity ( $e=0.15$ ), according to Bopp (1980).

Although BY Dra systems are main-sequence stars, their evolutionary stage is not clear. OU Gem has been listed by Soderblom et al. (1990) and Montes et al. (1999) as a possible member of the UMa moving group (300 Myr), and this suggests it may be a young star.

In this paper we present multiwavelength optical observations of chromospherically active binary system OU Gem.

## 2. Observations

Spectroscopic observations in several optical chromospheric activity indicators of OU Gem and some inactive stars of similar spectral type and luminosity class

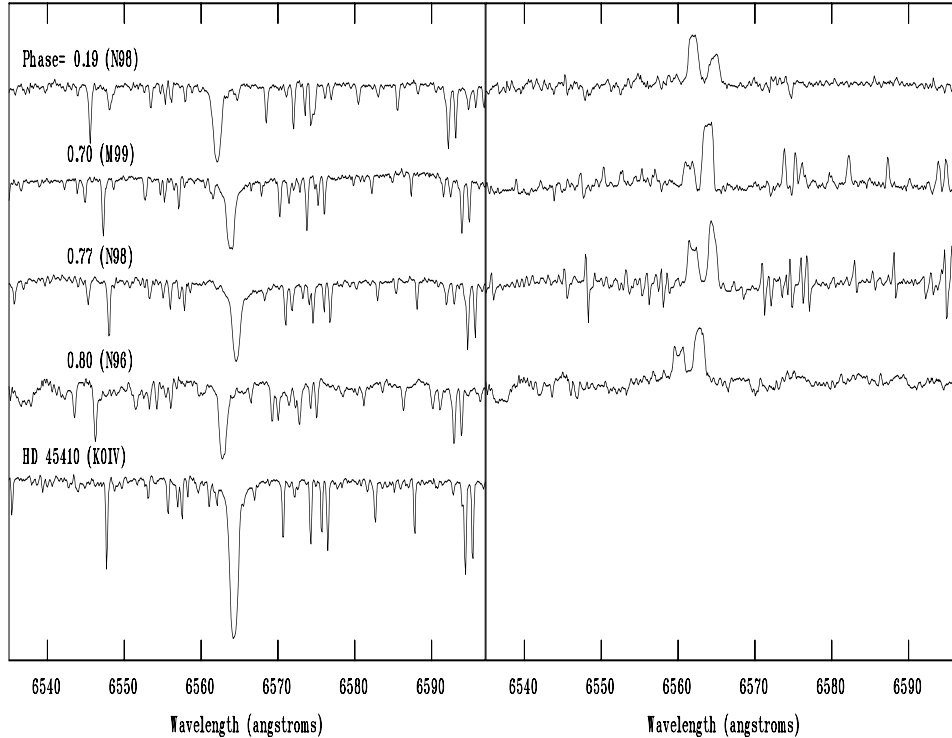


Figure 1. The left panel shows the OU Gem observed spectra and the HD 45410 (K0IV) reference star, in the H $\alpha$  line region. The right panel shows the OU Gem subtracted spectra.

have been obtained during three observation runs.

1) Two runs were carried out with the 2.56 m Nordic Optical Telescope (NOT) at the Observatorio del Roque de Los Muchachos (La Palma, Spain) in March 1996 and April 1998, using the SOFIN echelle spectrograph covering from 3632 Å to 10800 Å (resolution from  $\Delta\lambda$  0.15 to 0.60 Å), with the 1152 $\times$ 770 pixels EEV P88200 CCD detector.

2) The last run was carried out with the 2.5 m INT at the Observatorio del Roque de Los Muchachos (La Palma, Spain) in January 1999 using Multi-Site Continuous Spectroscopy (MUSICOS), covering from 3950 Å to 9890 Å (resolution from  $\Delta\lambda$  0.15 to 0.40 Å), with the 2148 $\times$ 2148 pixels SITe1 CCD detector.

In the three runs we obtained 4 spectra of OU Gem at different orbital phases. The stellar parameters of OU Gem have been adopted from Strassmeier et al. (1993), except for distance (given by the Hipparcos catalogue (ESA 1997)), the B-V color index and the radius (taken from the spectral type). The spectra have been extracted using the standard reduction procedure of the IRAF package (bias subtraction, flat-field division and optimal extraction of the spectra). The wavelength calibration was obtained by taking spectra of a Th-Ar lamp, for NOT runs, and a Cu-Ar lamp, for INT runs. Finally the spectra have been normalized by a polynomial fit to the observed continuum. The chromospheric

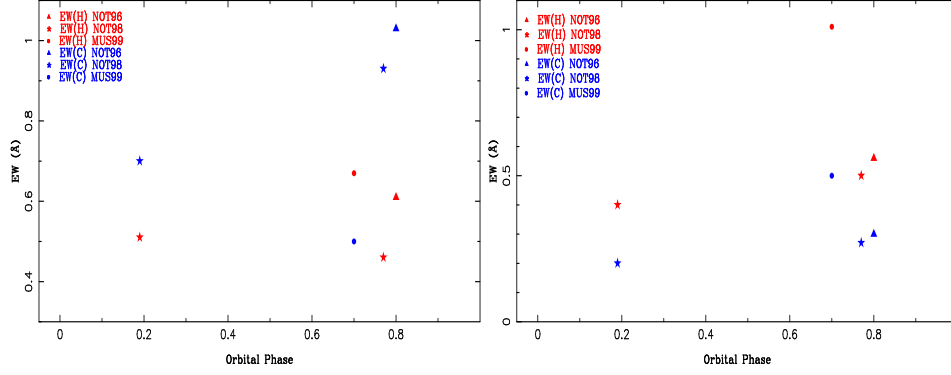


Figure 2. The left panel shows excess  $H\alpha$  emission equivalent width versus the orbital phase for the hot component (H) and for the cool component (C) in all observation runs. The right panel shows the same for the  $Ca\ II\ \lambda 8662$  line.

contribution in the activity indicators has been determined using the spectral subtraction technique (Montes et al. 1995a, b).

### 3. The $H\alpha$ line

We have taken several spectra of OU Gem in the  $H\alpha$  line region in three different runs and at different orbital phases. The line profiles are displayed in Fig. 1. For each observation, we have plotted the observed spectrum (left panel) and the subtracted spectrum (right panel). In the observed spectra, we can see an absorption line for the primary star and a nearly complete filling-in for the secondary star. After applying the spectral subtraction technique, clear excess  $H\alpha$  emission is obtained for the two components, being stronger for the hot one. The excess  $H\alpha$  emission equivalent width (EW) is measured in the subtracted spectrum and corrected for the contribution of the components to the total continuum. We took one spectrum in this region in Dec-92 (Montes et al. 1995b). At the orbital phase of this observation ( $\varphi = 0.48$ ) we could not separate the emission from both components and we measured the total excess  $H\alpha$  emission EW. We obtained a similar value to Mar-96, Apr-98 and Jan-99 values obtained adding up the excess emission EW from the two components. In Fig. 2 we have plotted the excess  $H\alpha$  emission EW versus the orbital phase.

### 4. The $H\beta$ line

Four spectra in the  $H\beta$  region are available, in three different runs and at different orbital phases. Looking at the observed spectra in Fig. 3, we can only see the  $H\beta$  line of the primary, in absorption. After applying the spectral subtraction technique, small excess  $H\beta$  emission is obtained for the two components. We have determined the excess  $H\beta$  emission EW in the subtracted spectra, the ratio of excess  $H\alpha$  and  $H\beta$  emission EW, and the  $\frac{E_{H\alpha}}{E_{H\beta}}$  relation:

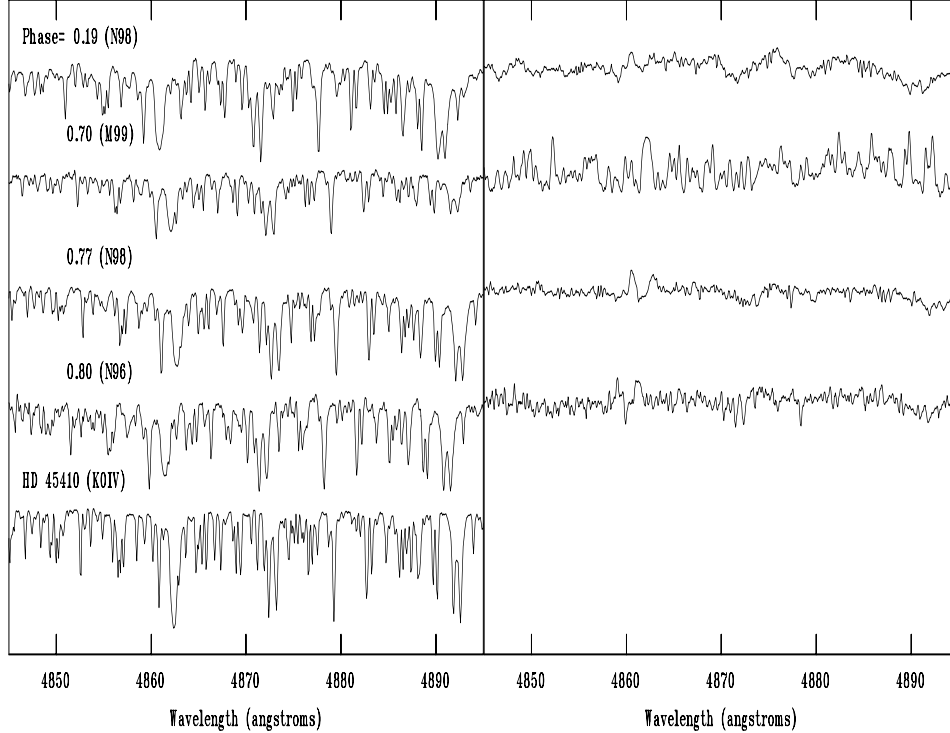


Figure 3. As in Fig. 1 for the  $H\beta$  line region.

$$\frac{E_{H\alpha}}{E_{H\beta}} = \frac{EW_{sub}(H\alpha)}{EW_{sub}(H\beta)} \cdot 0.2444 \cdot 2.512^{(B-R)} \quad (1)$$

given by Hall & Ramsey (1992) as a diagnostic for discriminating between the presence of plagues and prominences in the stellar surface. We have obtained high  $\frac{E_{H\alpha}}{E_{H\beta}}$  values for the two components, so the emission can come from prominences.

## 5. The Ca II IRT lines

The Ca II infrared triplet (IRT)  $\lambda 8498$ ,  $\lambda 8542$ , and  $\lambda 8662$  lines are other important chromospheric activity indicators. We have taken several spectra of OU Gem in the Ca II IRT lines region in three different runs and at different orbital phases, the three Ca II IRT lines are only included in MUSICOS 99 observation run. In the observed spectra, we can see both components of OU Gem show these lines in emission superimposed to the corresponding absorption (Fig. 4). After applying the spectral subtraction technique, clear excess emission appears for the two components, being stronger for the hot one. In Fig. 2 we have plotted the Ca II  $\lambda 8662$  EW versus the orbital phase for the hot and cool components.

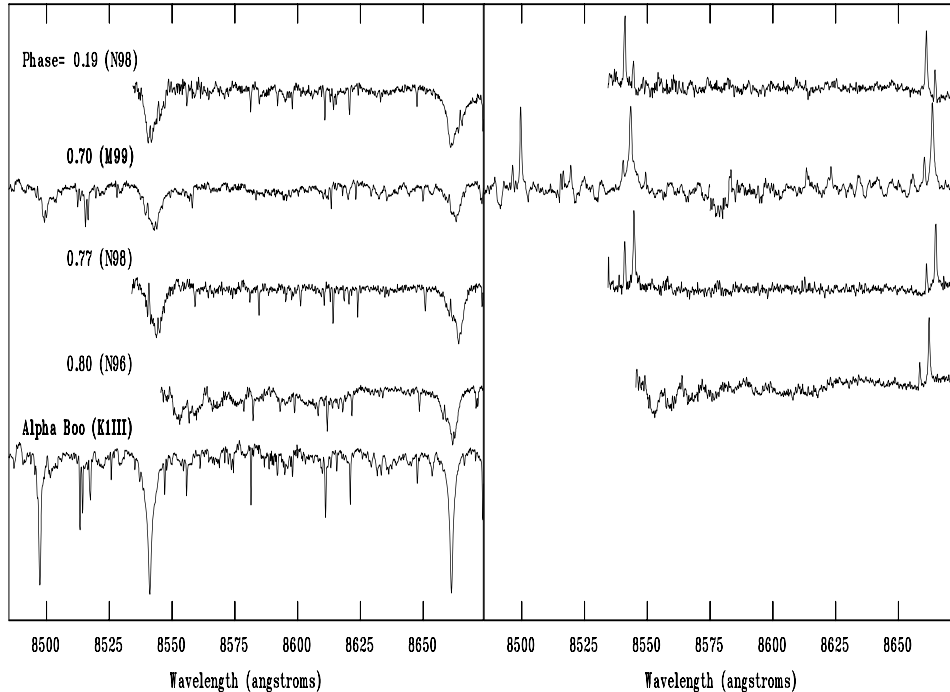


Figure 4. As in Fig. 1 for the Ca II IRT lines region.

## 6. The Ca II H & K and H $\epsilon$ lines

We have taken three spectra in the Ca II H & K lines region during the two NOT (96 & 98) observation runs. In Fig. 5 we can observe that both components of this binary have the Ca II H & K and H $\epsilon$  lines in emission. We can also see that the hot star's excess Ca II H & K emission is bigger than the cool star's. At 0.19 orbital phase, we only see the H $\epsilon$  line of the cool component because the H $\epsilon$  line of the hot star is overlapped with the Ca II H line of the cool one. At the other orbital phases, we can only see the H $\epsilon$  line of the hot component because the H $\epsilon$  line of the cool one is overlapped with the Ca II H line of the hot star. We took one spectrum in this region in Mar-93 (Montes et al. 1995a, 1996), with the 2.2 m telescope at the German Spanish Astronomical Observatory (CAHA). At the orbital phase of this observation ( $\varphi = 0.47$ ) we could not separate the emission from both components and we measured the total excess Ca II K & H emission EW. We obtained similar values to Mar-96 and Apr-98 values obtained adding up the excess emission EW from the two components, though we note that the Apr-98 values are slightly bigger than the others.

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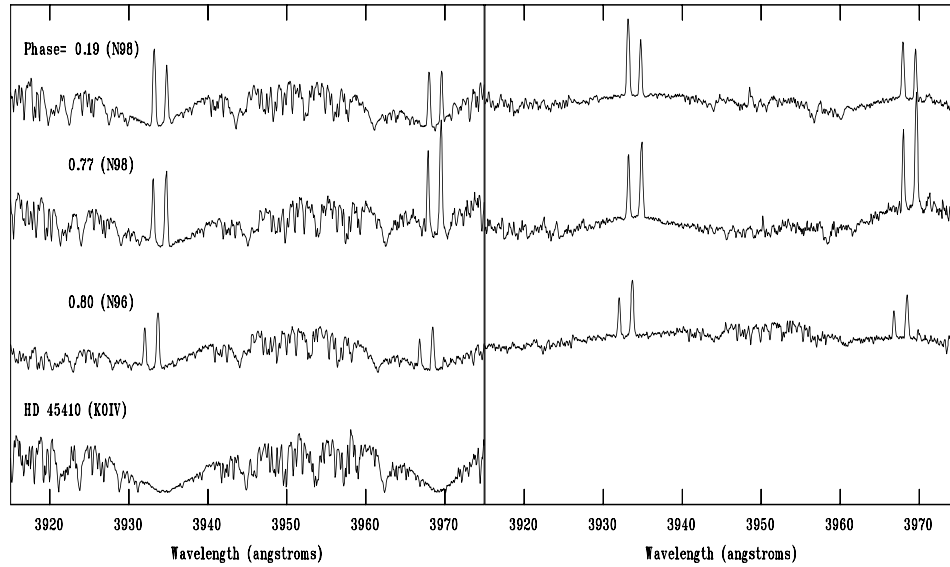


Figure 5. As in Fig. 1 for the Ca II H & K line region.

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